TOWARDS PERSONALIZED PHYSICAL ACTIVITY PROGRAMS TO REDUCE THE RISK OF FALLING IN OLDER ADULTS

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SMART AGEING AND HEALTHY LIFE Summer School - 23/09/2021

Co-funded by the Erasmus+ Programme of the European Union

Plan

Introduction

- Risk of falling and ageing
- Balance and causes of falls
- Risk of falling and clinical environment

Balance recovery during transitions and personalized balance assessment

- Focus on balance transitions
- A multifactorial assessment protocol
- Best predictors of the risk of falling
- Profiling and individualized care

Perspectives

- Environment in Poitiers
- Projects (ongoing and future)

1. INTRODUCTION

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Risk of falling and ageing

Falls are the leading cause of injury-related death among adults aged 65 and older, with more than 1/3 falling at least once a year.

A fall is defined as "an event which results in a person coming to rest inadvertently on the ground or floor or other lower level".

Discrete event, not something that happens regularly

Unpredictable, not desired

Fall?

https://www.sfu.ca/tips/fallvideos.html

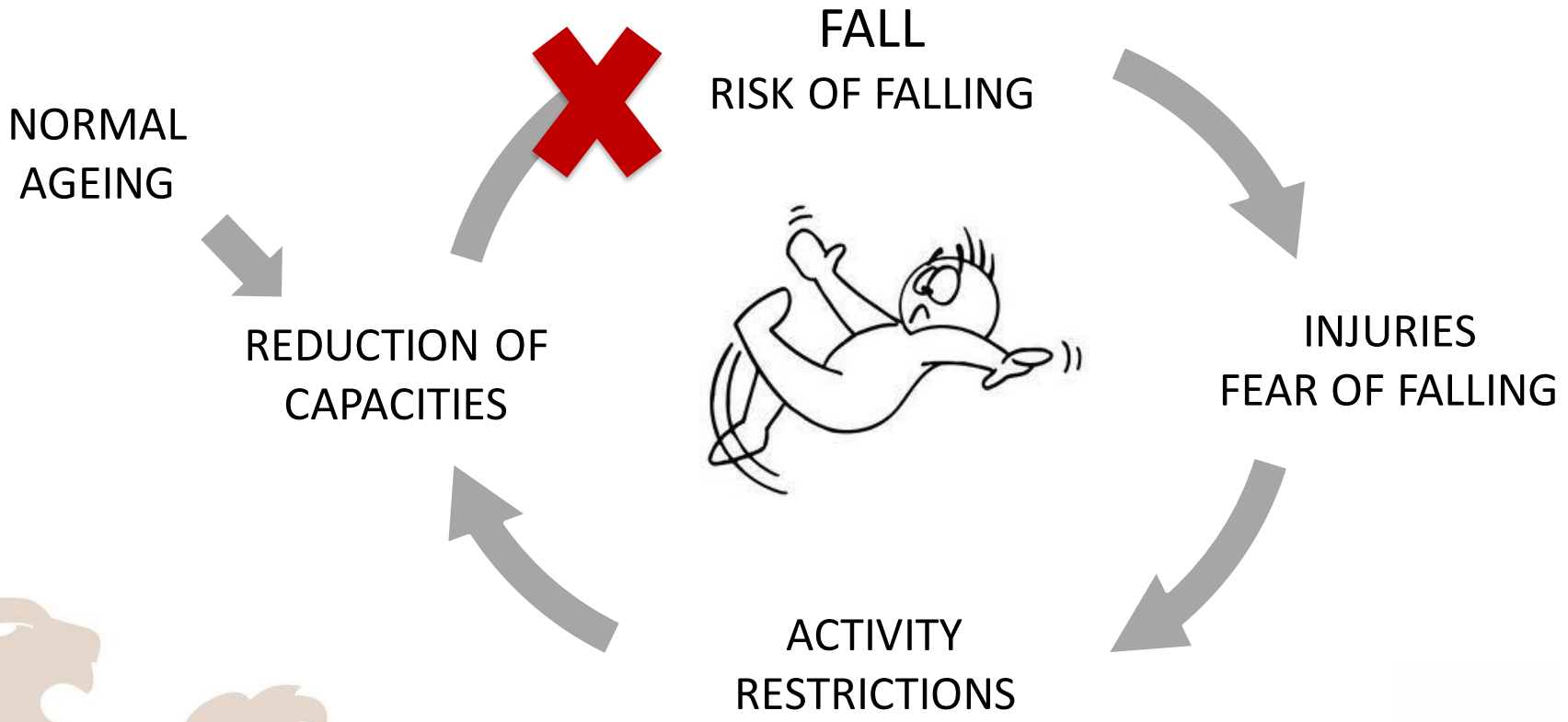
https://www.youtube.com/watch?v=uV-f-x1Pli4

World Health Organization (2008) *General report on falls*

Risk of falling and ageing

Why do elderly people fall? The post-fall syndrome

Community-dwelling elderly people are mostly concerned by their 1st fall



Murphy & Isaacs (1986) *The post-fall syndrome*, J Gerontology 28, 265–270

Risk of falling and ageing

Why do elderly people fall? Falling factors

Age is usually the first fall risk factor …
… but there are plenty of other factors → more than 400! (Masud & Morris, 2001)

Table I. Risk factors for hip fracture in 9,516 white women [32]

- Age
- Maternal hip fracture
- Height at age 25 years
- Lack of weight gain since 25 years
- Self related health
- Current h…
- …
- Lack of walking for exercise
- On feet ⩽4 hours/day
- Inability to ris…
- Poo…

Geometry
Bone mass
Microarchitecture
Bone mineral structure
Bone turnover

Most likely cause of fall

Risk factor	Significant/total	Mean %	Range
Accident/environment-related	11/11		(1–53)
Gait/balance disorders or weakness	9/9		(4–39)
Dizziness/vertigo	9/9		(0–30)
Drop attacks	8/9		(0–52)
Confusion	5/9		(0–14)
Weakness	4/8		(0–24)
Balance deficit	5/9		(0–5)
Mobility limitation	2/7		(0–3)
Gait deficit			(2–39)
Visual deficit			(0–21)
Cognitive impairment			
Impaired ADL			
Postural hypotension			

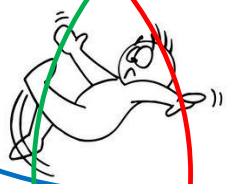
Masud & Morris (2001) *Epidemiology of falls*, Age Ageing 30: 3-7

Risk of falling and ageing

Falling consequences

Physical

- Dislocations, fractures
- Pain, bruises, wounds
- Death



Psychological

- Fear of falling
- Depression

Sociological

- Isolation, solitude
- Loss of autonomy
- Activity restriction
- Costs

Risk of falling and ageing - Synthesis

Falling becomes a major health problem as we age because it has serious consequences.

Therefore we need to improve fall prevention and care for our elderly population.

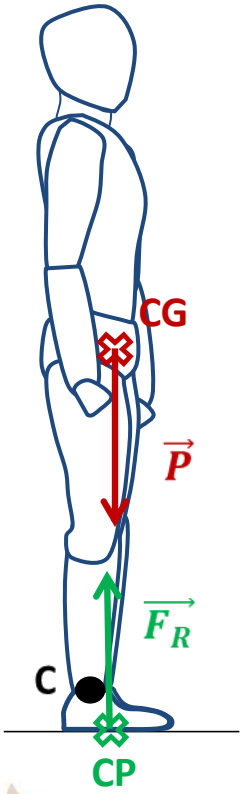
When it comes to fall risk identification, we naturally think of balance
→ But “which” balance to assess?

Balance & causes of falling

What is balance?

Balance (mechanics)

Static balance?

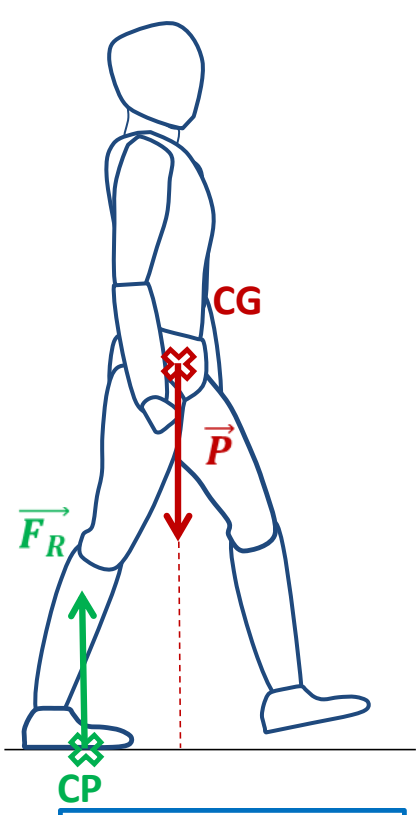


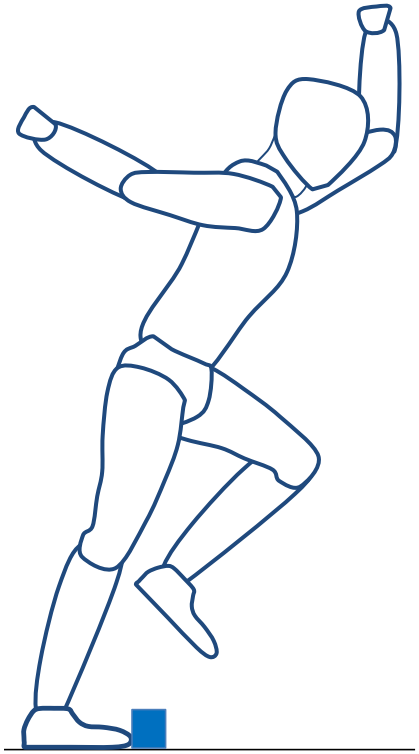
$$\sum \vec{F}_{ext \rightarrow système} = \vec{0}$$

$$\sum \vec{M}\left(\vec{F}_{ext \rightarrow système}\right)_{/C} = \vec{0} \quad \forall C$$

Mechanically impossible in living organisms

Dynamic balance?





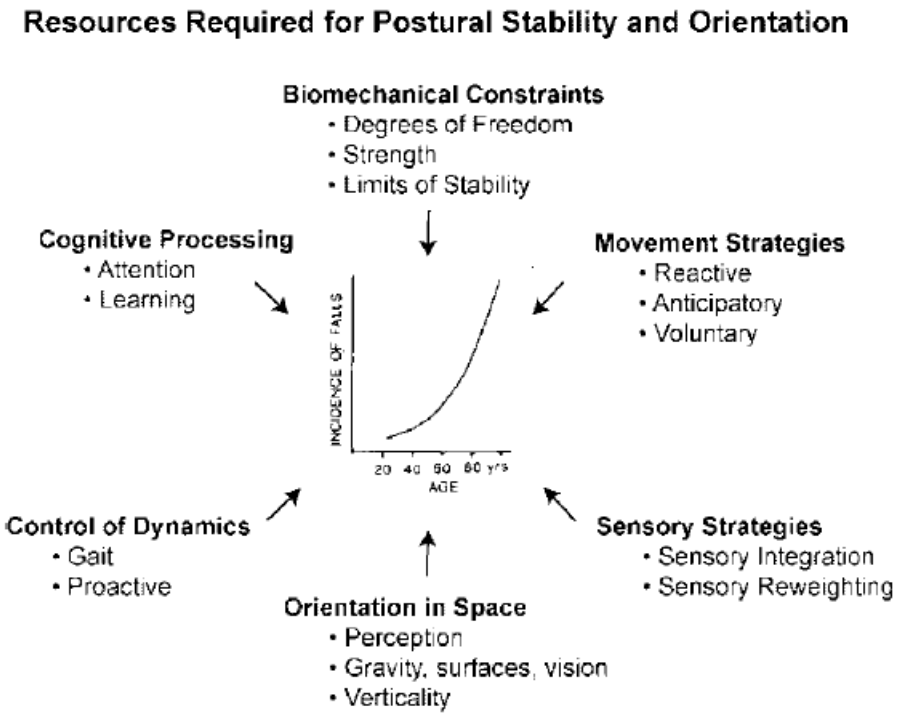
$$\sum \overrightarrow{F_{ext}} = m \,.\, \vec{a}$$

$$\sum \overrightarrow{M_{ext}} = I \,.\, \vec{\alpha}$$

Permanent "state"

Balance (motor control)

Approaching balance control through its main resources

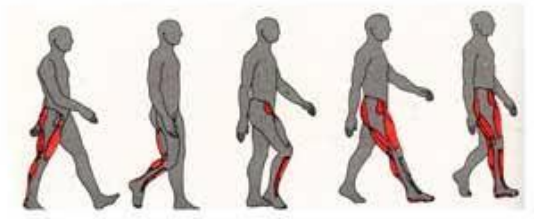


Horak (2006) *What do we need to know about neural control of balance to prevent falls*, Age Ageing 35: 7-11

Balance (motor control)

Balanced body = controlled – desired – chosen – predictable state
→ Controlled by the Central Nervous System

Opposed the definition of falling, which implies the term “inadvertently”
→ Unpredictable



Two main control mechanisms:

- **Steady-state** : “repetitive” and predictable + CG velocity is constant

- **Reactive** : balance recovery following an unpredictable perturbation + CG velocity changes (= acceleration/deceleration)

Granacher et al. (2012) *A qualitative review of balance and strength performance in healthy older adults: impact for testing and training* , Journal of Ageing Research 1-16

Causes of fall (mechanics & control)

External perturbation of the system

Something put the system (the body) in a mechanical unbalanced state

The steady-state is no longer maintained

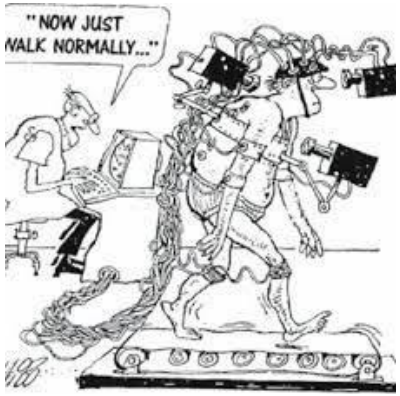
Balance recovery actions

Mobilize the individual reactive capacities to slow down the fall

If you fail, you will fall
If you succeed, you will be fine

Risk of falling & clinical environment

Testing in a clinical environment brings some constraints

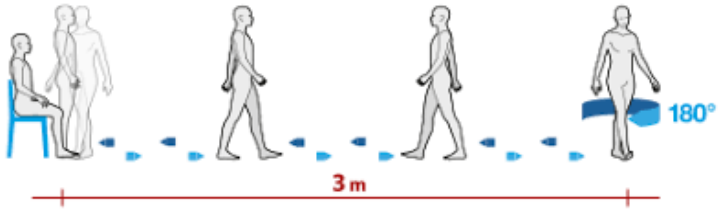


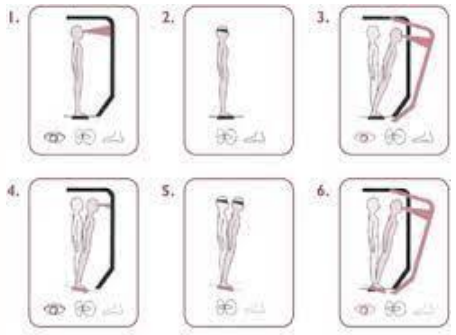
Clinicians needs for fall risk assessment
→ Personalized and reliable diagnosis

Risk of falling & clinical environment

How do we identify a fall risk in elderly people?

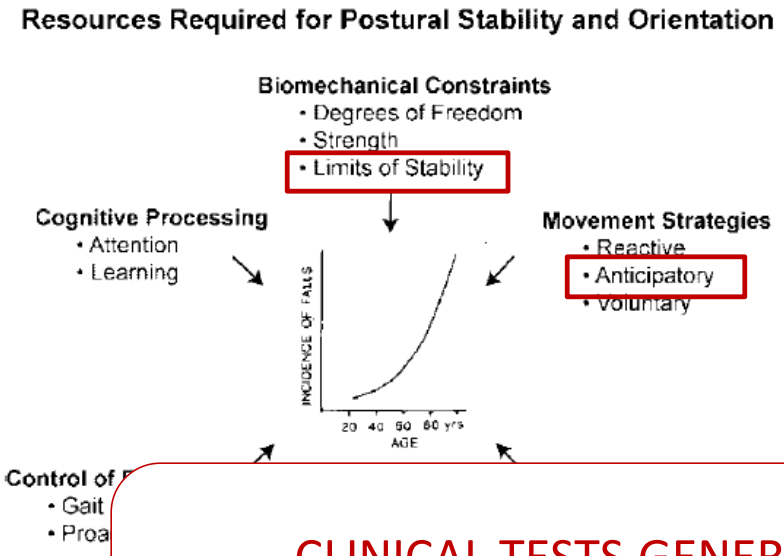
We test people…
… but there are plenty of tests!





Balance (motor control)

Approaching balance control through its main resources



Generally…
No balance recovery
No unpredictability

CLINICAL TESTS GENERALLY DO NOT DISCRIMINATE COMMUNITY-DWELLING ELDERLY FALLERS AND NON-FALLERS
(Mancini & Horak, 2011)

Mancini & Horak (2011) *The relevance of clinical balance assessment tools*, Eur J Phys Rehab Med 46(2): 239-248

Introduction - Synthesis

Scientific challenges for an efficient fall risk prevention in the elderly

- Focus on the community-dwelling elderly: population mostly concerned by the 1st fall and development of the post-fall syndrome

- Look more closely at the factors controlling balance recovery actions, in unpredictable situations

- Use balance tests that fit with clinical constraints and measure appropriate deficits to personalize fall prevention procedures

→ **Predict the likelihood of an elderly person to fall remains extremely difficult**

Working hypothesis: better identification of the risk with a personalized assessment of balance resources

2. BALANCE RECOVERY DURING TRANSITIONS AND PERSONALIZED BALANCE ASSESSMENT

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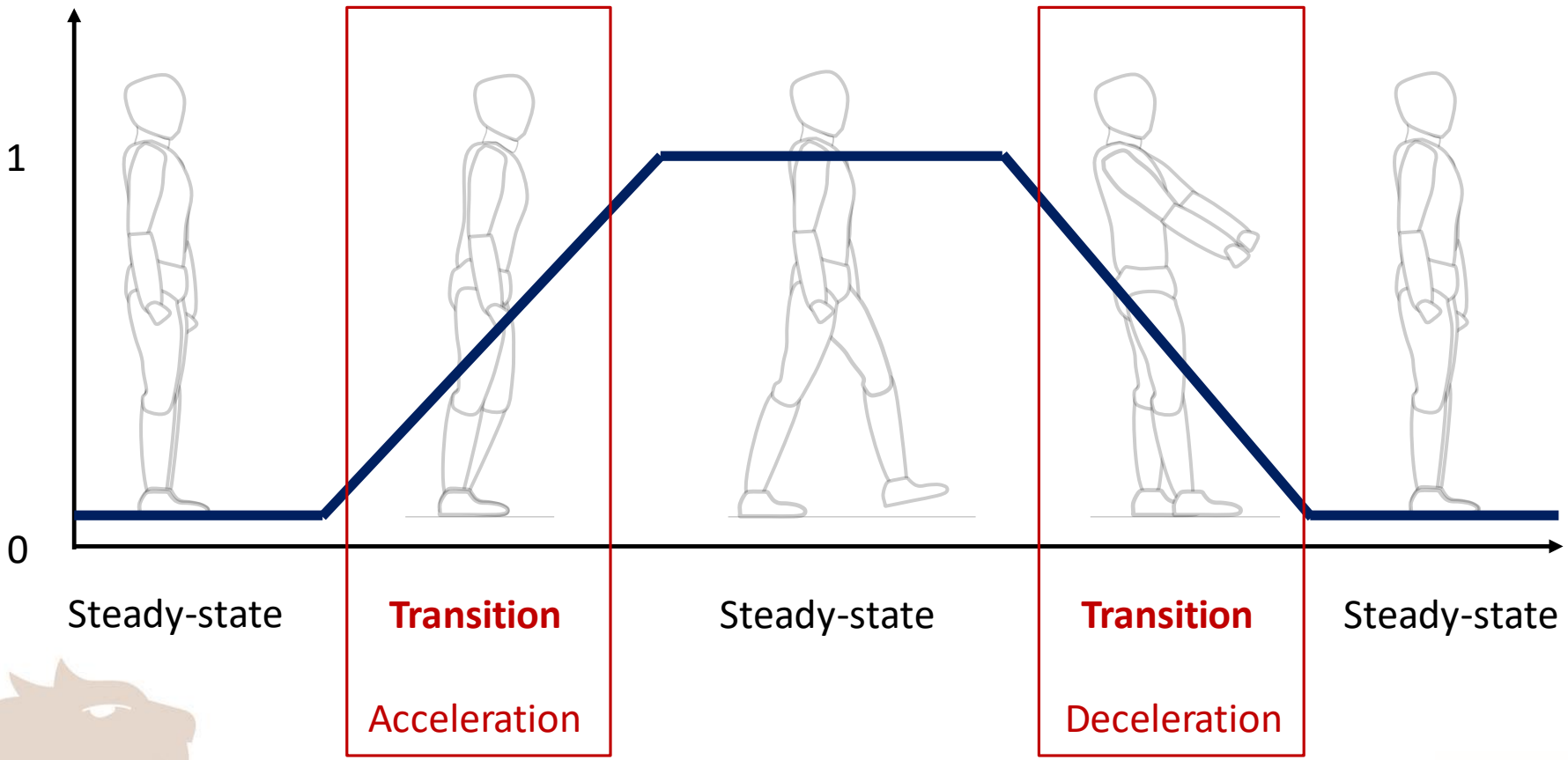
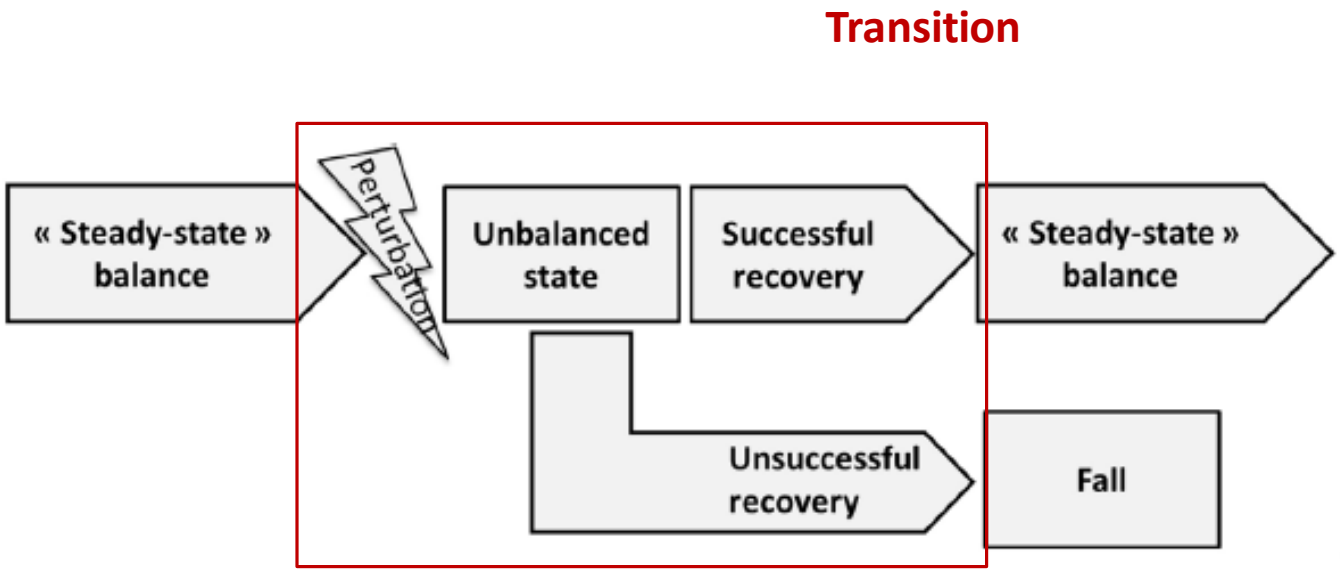
Balance and (loco)motor transitions



Granacher et al. (2012) *A qualitative review of balance and strength performance in healthy older adults: impact for testing and training* , J of Ageing Research 1-16

Focus towards balance recovery



Hypothesis : better fall risk identification in community-dwelling elderly fallers through the characterization of their balance recovery response to an **unpredictable stimulus.**

Tisserand et al. (2015) *Comparison between investigations of induced stepping postural responses and voluntary steps to better detect community-dwelling elderly fallers*, Neurophysiologie Clinique 45: 269-284

Population & Protocol

Group	Nb	Age (years)	Height (m)	Weight (kg)
Non-fallers (NF)	26	**74,2 (3,9)**	1,64 (0,09)	65,3 (11,9)
Fallers (C)	21	**76 (3,9)**	1,61 (0,1)	68,6 (12,2)

Hospices Civils de Lyon

CRP

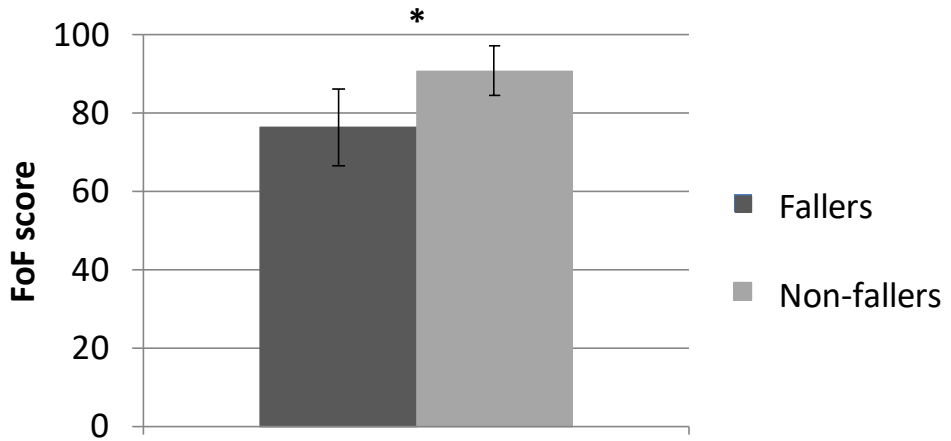
Centre de Prévention Agirc-Arrco Rhône - Alpes

Main measurements

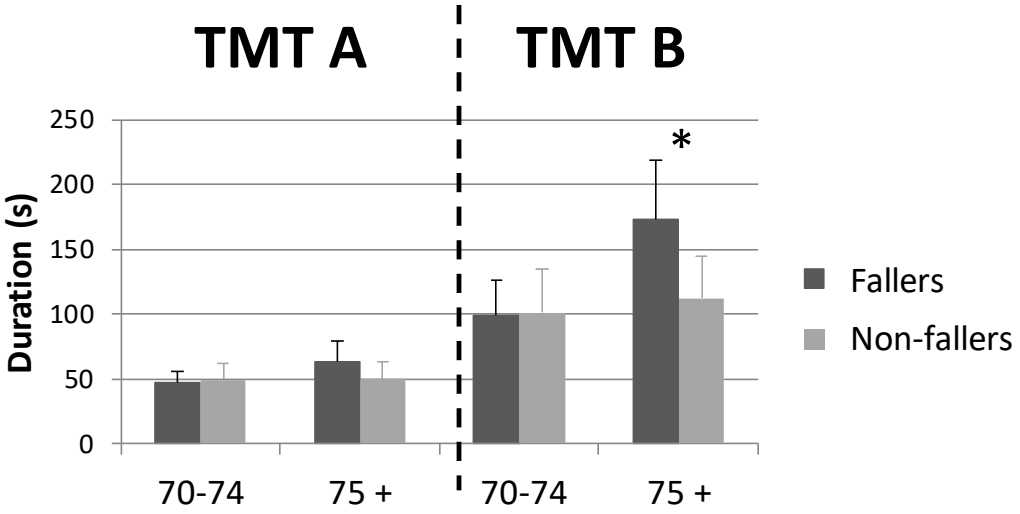
- Psychological and cognitive (fear of falling, inhibition, fluence, attention, physical activity)
- Clinical balance tests (unperturbed posture and gait)
- Voluntary step in unpredictable choice reaction time
- Protective step to unpredictable perturbation

Tisserand (2015) *Mécanismes du rattrapage de l'équilibre et évaluation du risque de chute chez une population âgée autonome*, Thèse de doctorat, Université de Lyon

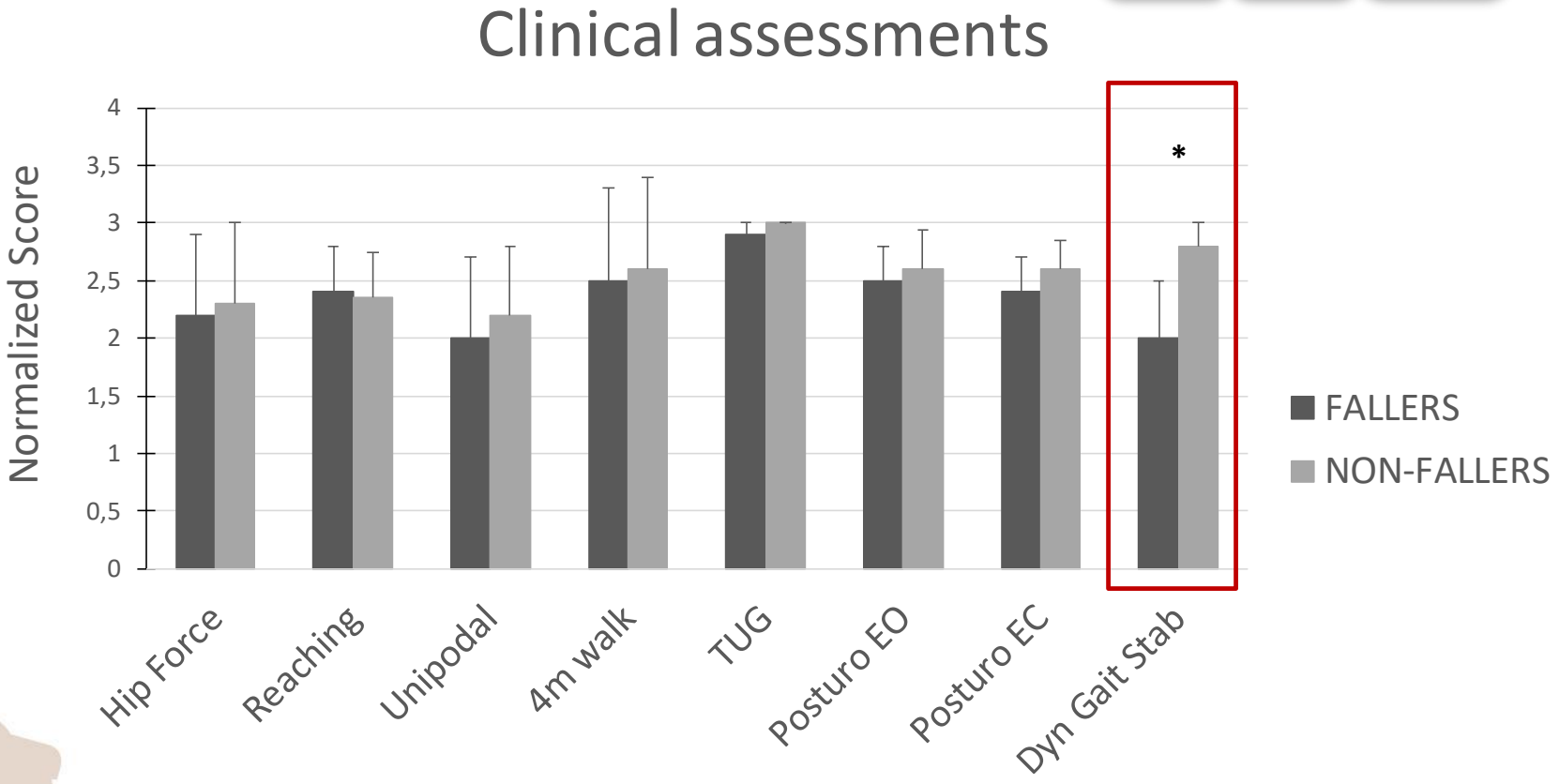
Psychological and cognitive tests



No other differences



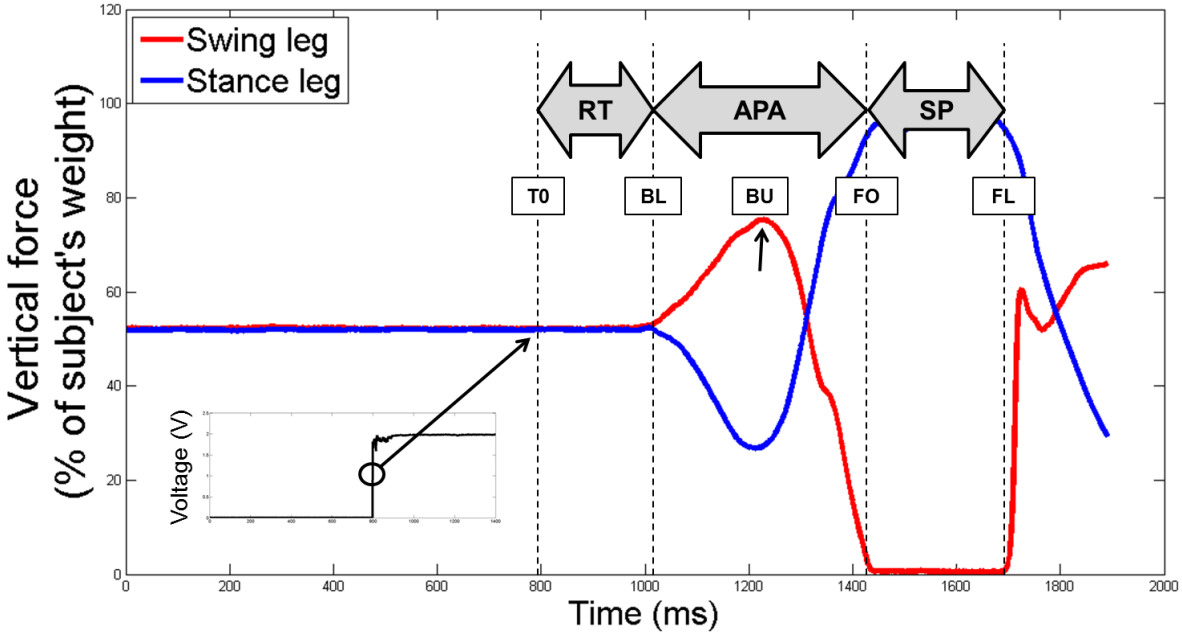
Clinical measurements



No differences!...
Except for dynamic stability during gait

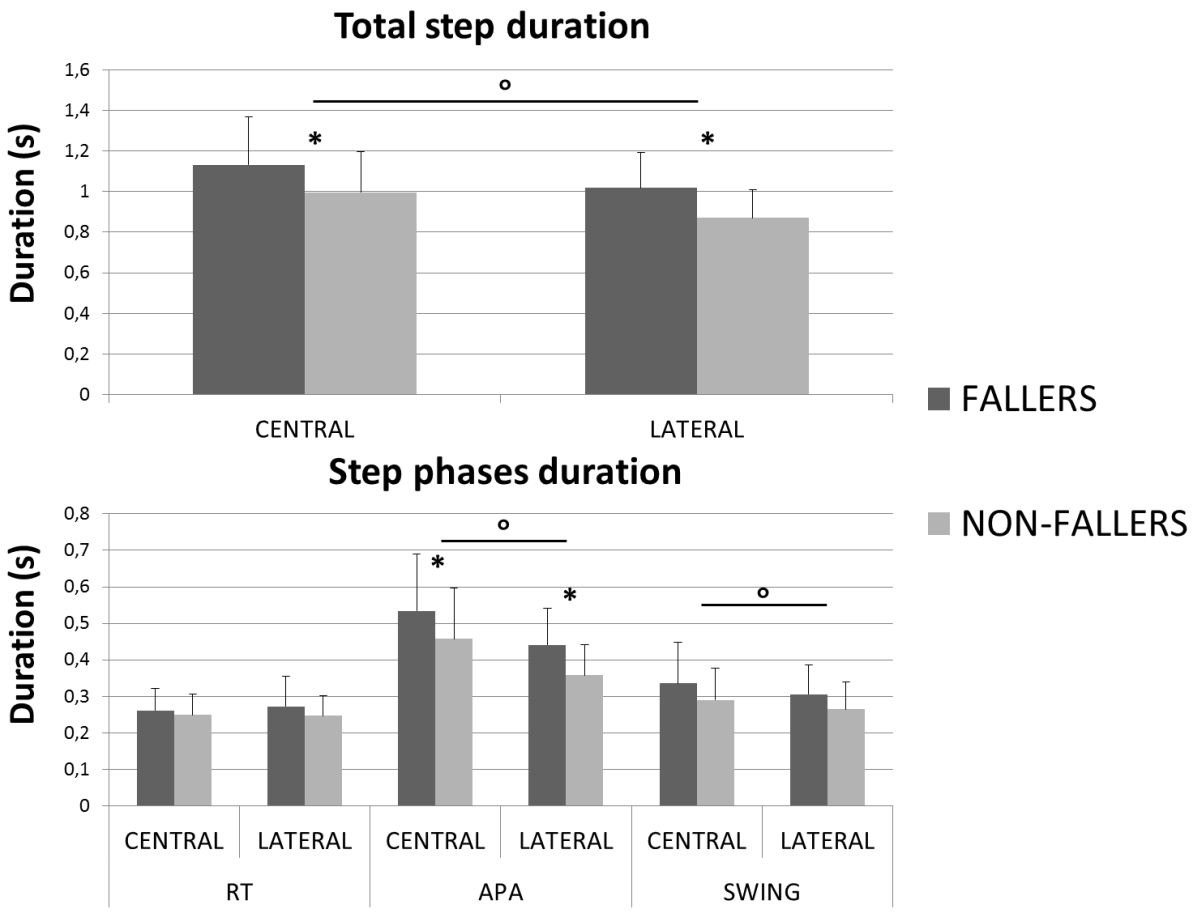
Voluntary step to unpredictable stimulus

Choice Stepping Reaction Time



Lord & Fitzpatrick (2001) *Choice stepping reaction time: a composite measure of fall risk in older people*, Journal of Gerontology, 56:10, M627-M632

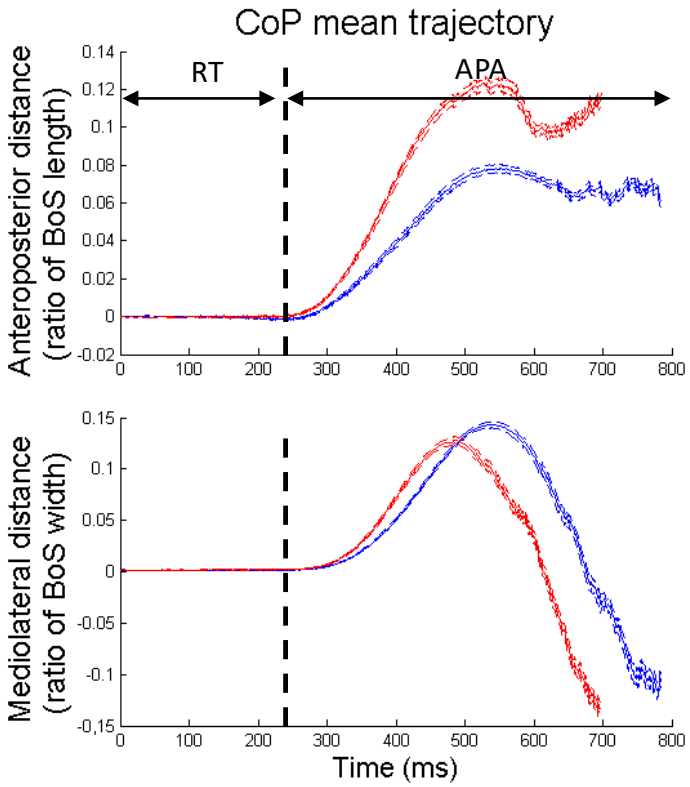
Voluntary step to unpredictable stimulus



Tisserand et al. (2016) *Elderly fallers enhance dynamic stability through anticipatory postural adjustments during a choice stepping reaction time*, Frontiers in Human Neurosciences, 10, 613

Voluntary step to unpredictable stimulus

Momentum



Dynamic stability

Tisserand et al. (2016) *Elderly fallers enhance dynamic stability through anticipatory postural adjustments during a choice stepping reaction time*, Frontiers in Human Neurosciences, 10, 613

Balance recovery and risk of falling

First conclusions

Difference between Fallers and Non-fallers occurs during the APA phase
→ **Transition between two steady-states**

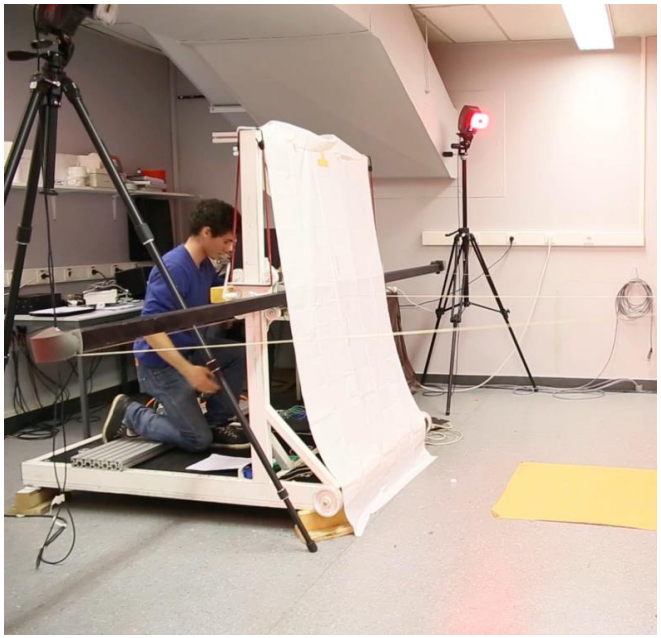
Among fallers

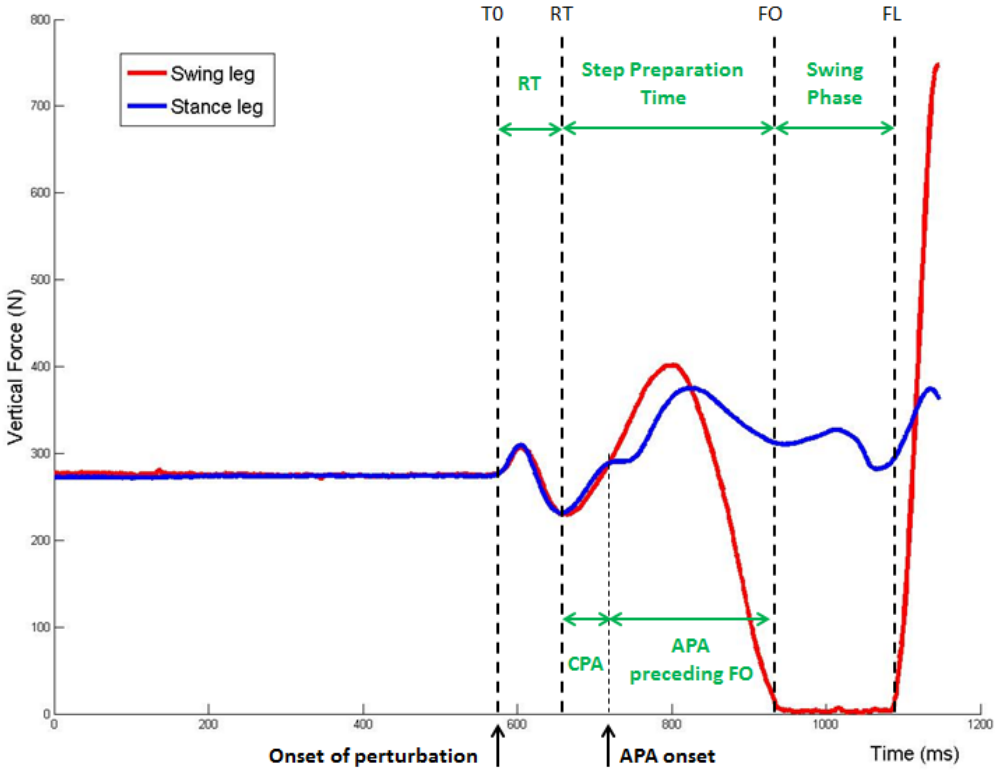
- **Momentum** production deficits
- **Larger** dynamic **stability**

→ **Fallers favor stability** instead of the instructions (being fast)
→ **A longer response duration is critical** in case of an external, unpredictable, perturbation

Protective step to unpredictable stimulus

Protective step – « waist-pull » paradigm

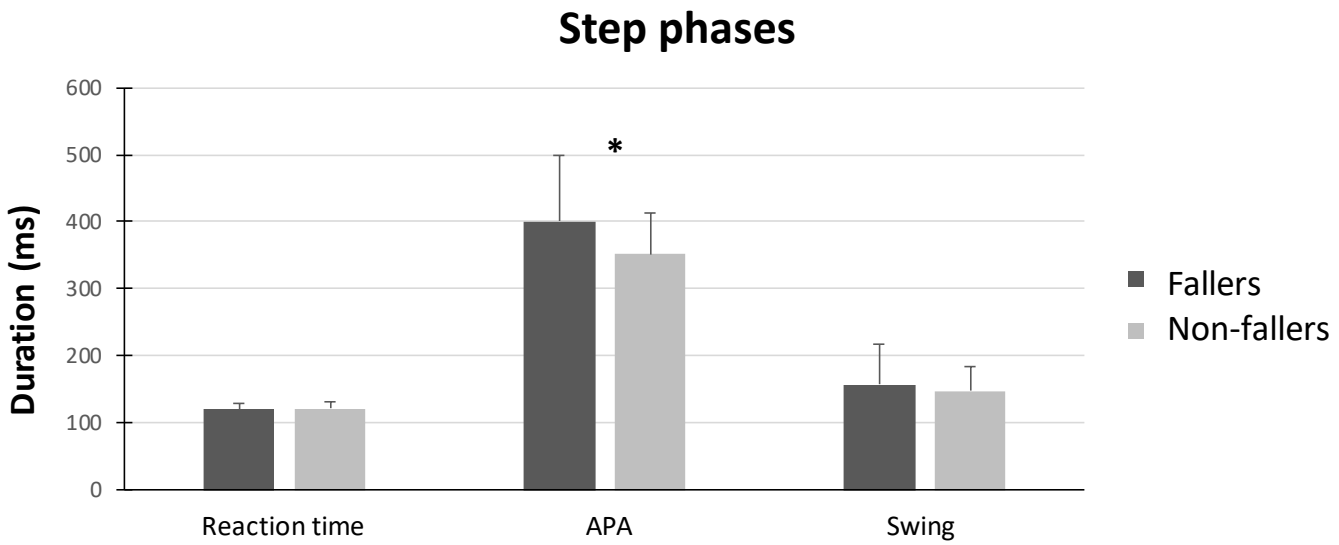


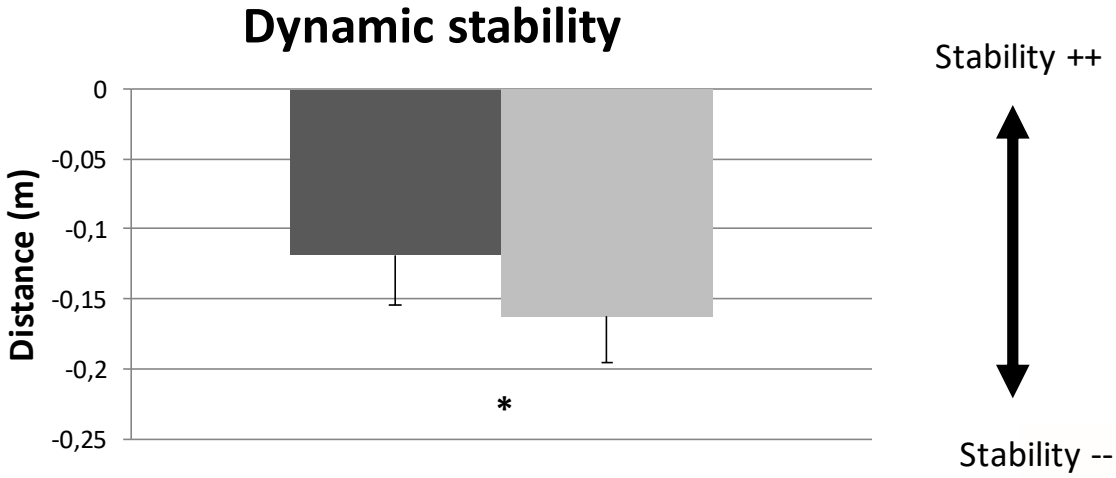


Pidcoe & Rogers (1998) *A closed-loop stepper motor waist-pull system for inducing protective stepping in humans*, Journal of Biomechanics, 31:4, 377-381

Tisserand et al. (2015) *Comparison between investigations of induced stepping postural responses and voluntary steps to better detect community-dwelling elderly fallers*, Neurophysiologie Clinique 45: 269-284

Protective step to unpredictable stimulus





Tisserand (2015) *Mécanismes du rattrapage de l'équilibre et évaluation du risque de chute chez une population âgée autonome*, Thèse de doctorat, Université de Lyon

Protective step to unpredictable stimulus

First conclusions

Two response strategies to the perturbation

	FALLERS	NON-FALLERS
Results	Increase step duration and dynamic stability	Decrease step duration and dynamic stability
Interpretation	Try to resist the perturbation without stepping Dangerous call	Main objective is to widen the base of support "Controlled" risk

Tisserand (2015) *Mécanismes du rattrapage de l'équilibre et évaluation du risque de chute chez une population âgée autonome*, Thèse de doctorat, Université de Lyon

Balance recovery and fall risk

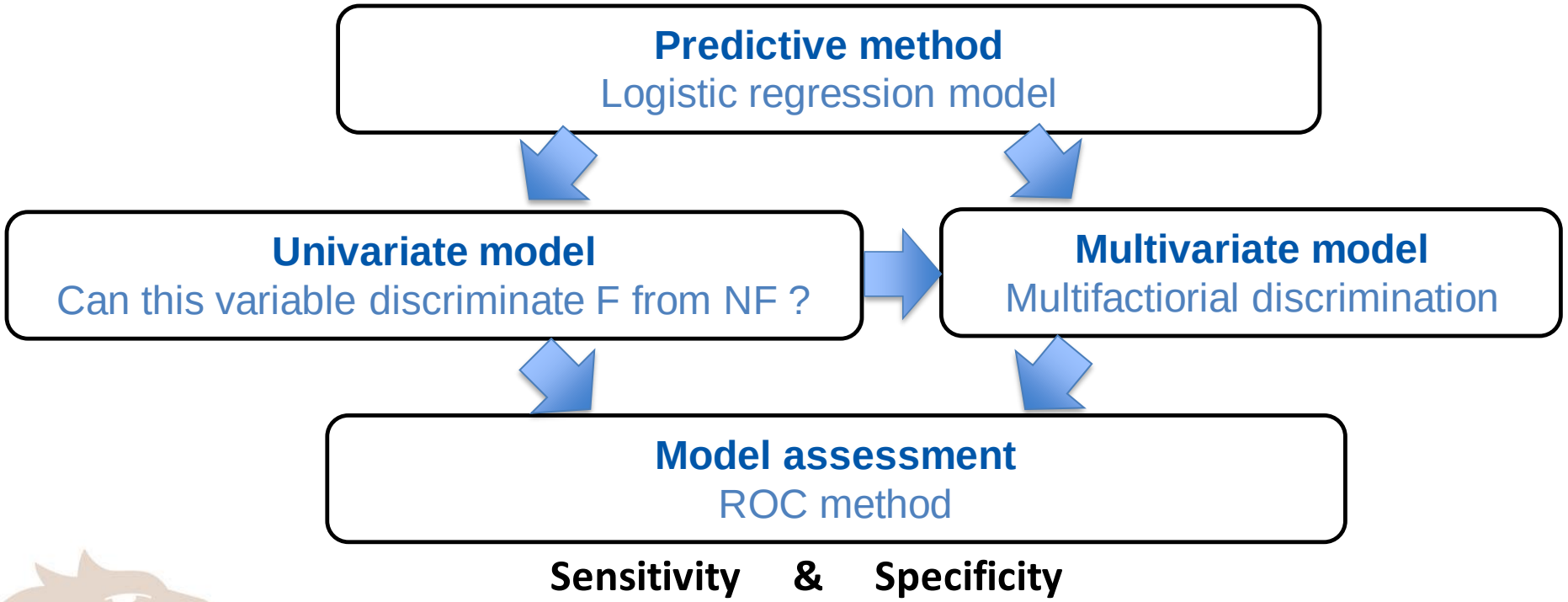
General conclusions

Clear distinction between fallers and non-fallers in dynamic, transition tasks, in response to an unpredictable stimulus (or perturbation).

Community-dwelling elderly with a higher risk of falling have a reduced capacity for adaptation.

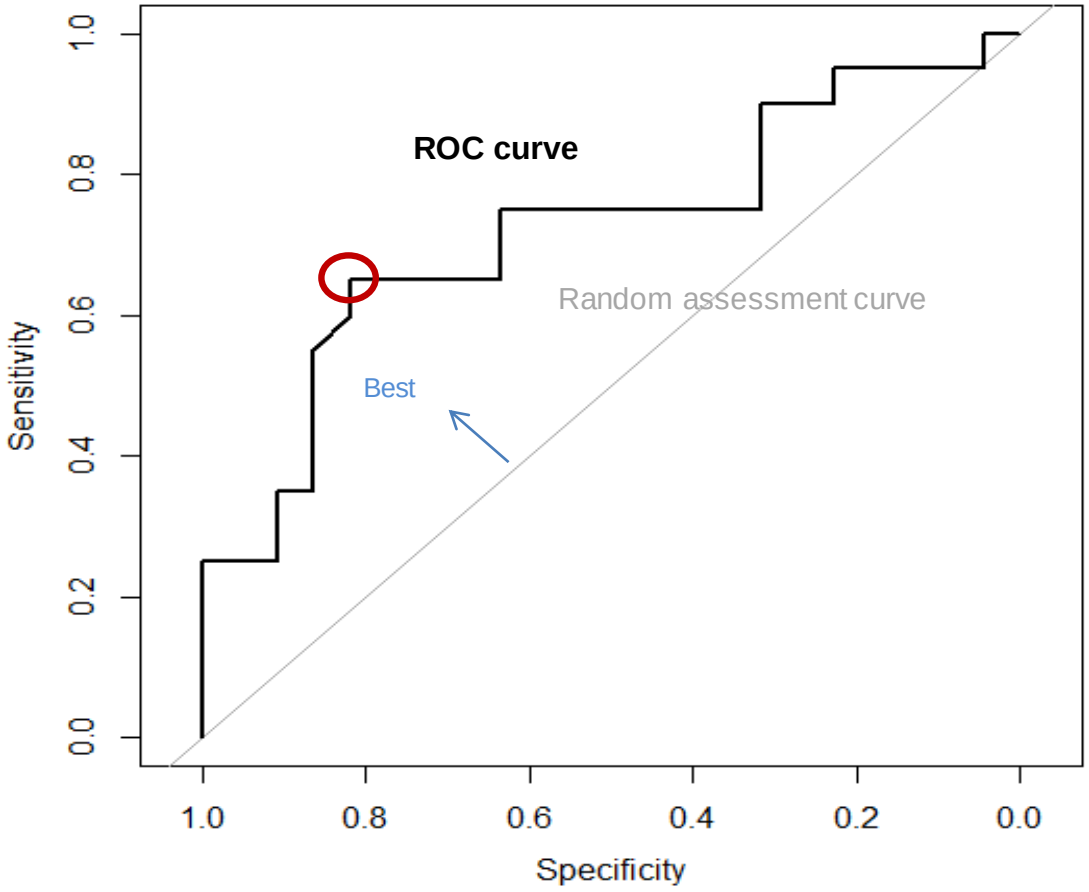
Fall risk predictors?

Statistical analysis using a predictive method



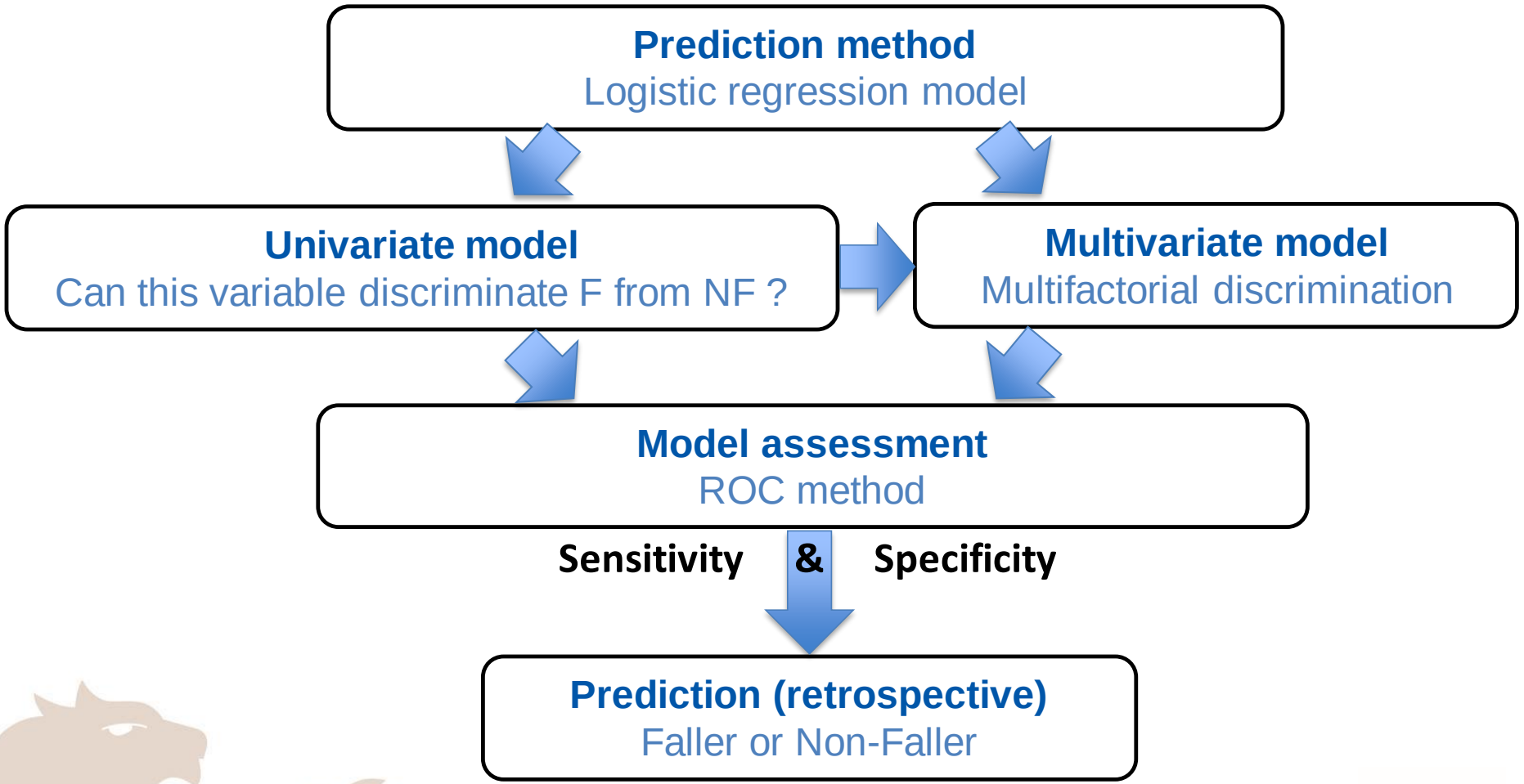
Coughlin et al. (1992). The logistic modeling of sensitivity, specificity, and predictive value of a diagnostic test. *J Clin Epidemiol* **45,** 1–7.

ROC method



Coughlin et al. (1992). The logistic modeling of sensitivity, specificity, and predictive value of a diagnostic test. *J Clin Epidemiol* **45,** 1–7.

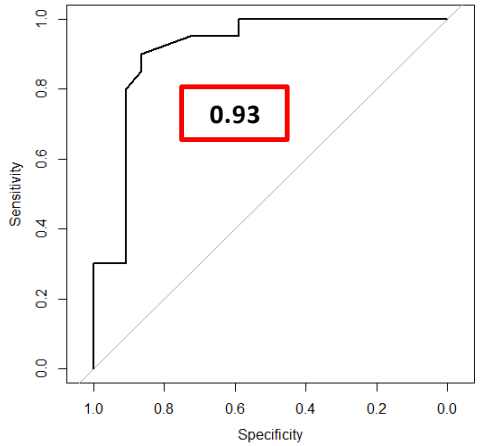
Statistical analysis



Fall risk criteria

Univariate model	p
Psycho-Cognitive	
Inhibition	*
Fear of falling	*
Clinical indexes	
Gait velocity	NS
Gait dynamic stability	*
Eyes closed posturography	NS
Timmed-up & Go	NS
Voluntary step	
Total duration	*
APA duration	*
Foot velocity peak	NS
Center of pressure velocity	·
Protective step	
Total duration	*
APA duration	·
Foot velocity peak	·

Multivariate model
P = f(v1, v2, v3, v4)



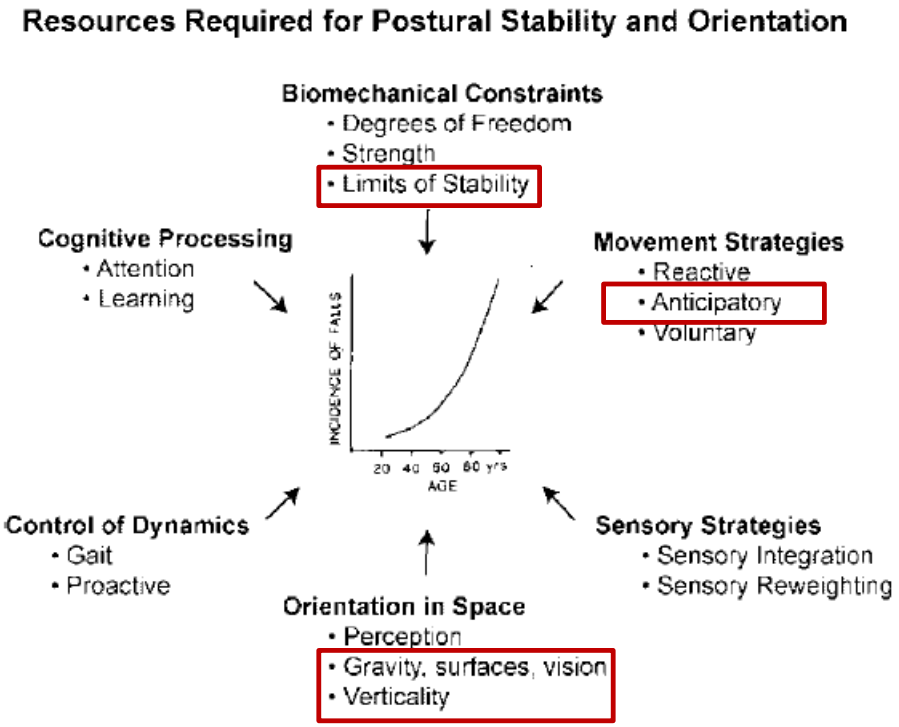
Threshold = 0.468

criteria

Participant X → P → Faller / Non-Faller

Horak's model

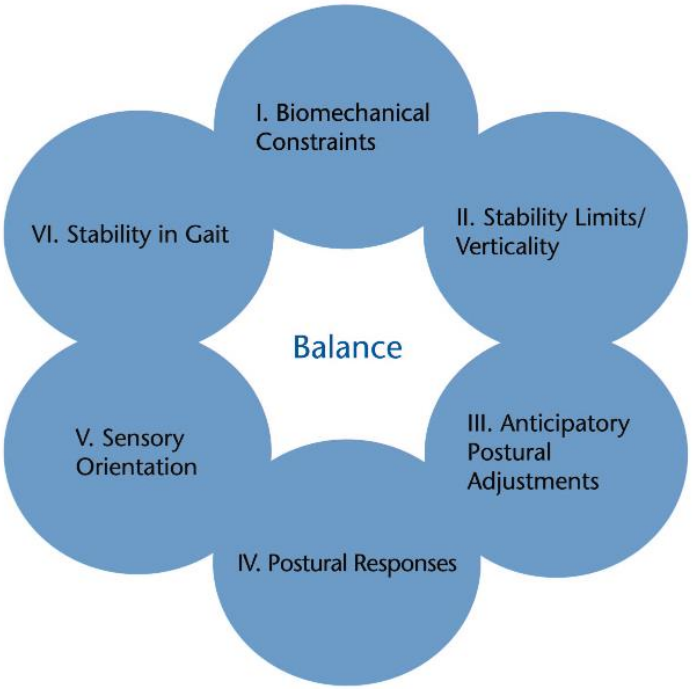
Approaching balance control through its main resources



Horak (2006) *What do we need to know about neural control of balance to prevent falls*, Age Ageing 35: 7-11

Horak's model

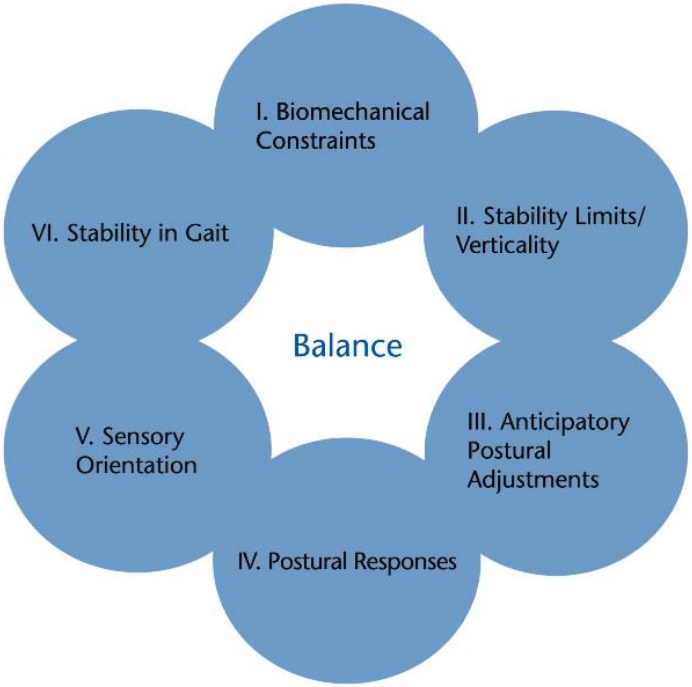
An example of balance testing through different resources, integrating clinical context

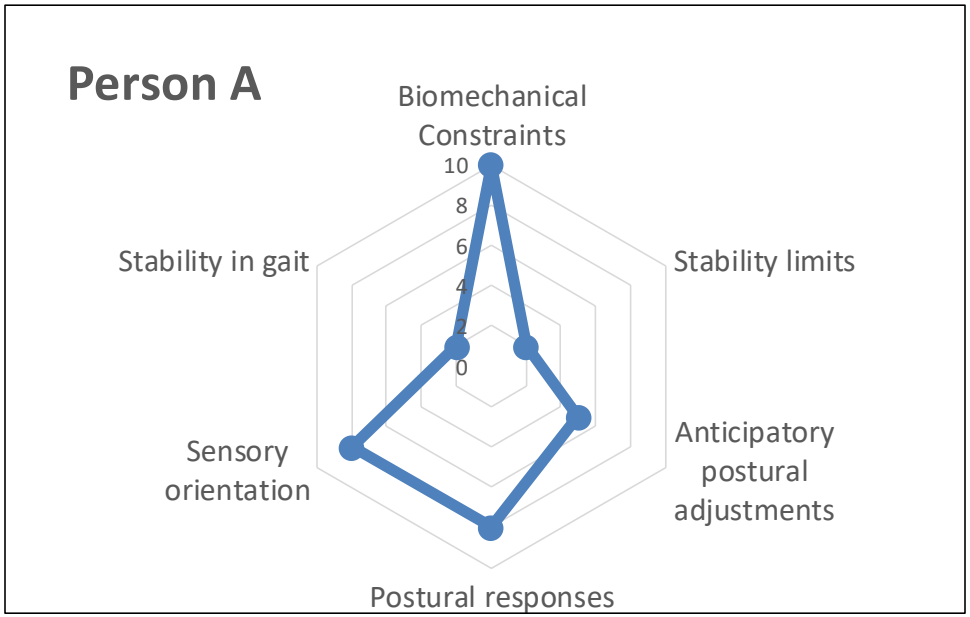


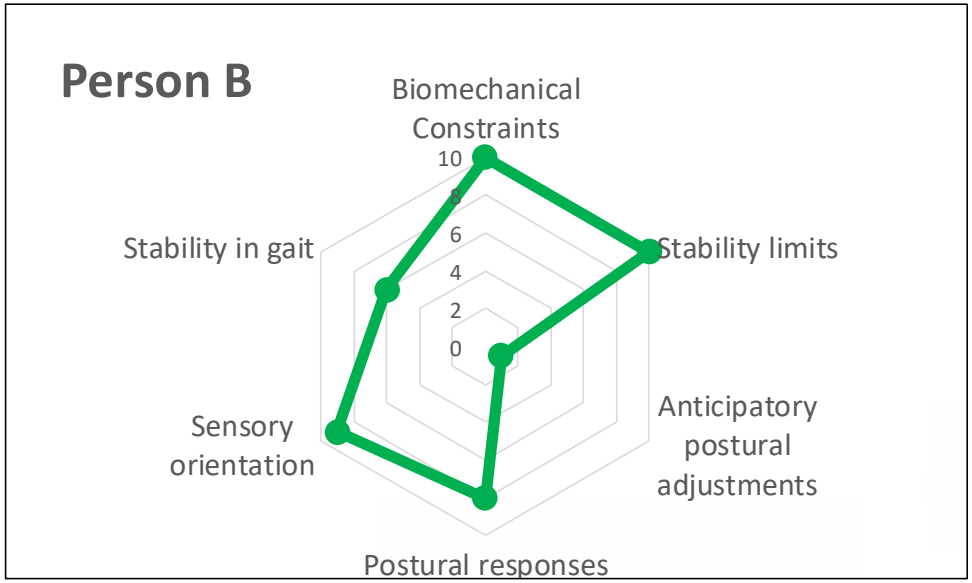
I. Biomechanical Constraints	II. Stability Limits/Verticality	III. Anticipatory Postural Adjustments	IV. Postural Responses	V. Sensory Orientation	VI. Stability in Gait
1. Base of support	6. Sitting verticality (left and right) and lateral lean (left and right)	9. Sit to stand	14. In-place response, forward	19. Sensory integration for balance (modified CTSIB) Stance on firm surface, EO Stance on firm surface,EC Stance on foam, EO Stance on foam, EC	21. Gait, level surface
2. CoM alignment	7. Functional reach forward	10. Rise to toes	15. In-place response, backward		22. Change in gait speed
3. Ankle strength and ROM	8. Functional reach lateral (left and right)	11. Stand on one leg (left and right)	16. Compensatory stepping correction, forward		23. Walk with head turns, horizontal
4. Hip/trunk lateral strength		12. Alternate stair touching	17. Compensatory stepping correction, backward	20. Incline, EC	24. Walk with pivot turns
5. Sit on floor and stand up		13. Standing arm raise	18. Compensatory stepping correction, lateral (left and right)		25. Step over obstacles
					26. Timed "Get Up & Go" Test
					27. Timed "Get Up & Go" Test with dual task

Horak et al. (2009) *The Balance Evaluation System Test to differentiate balance deficits*, Physical Therapy 89: 484-498

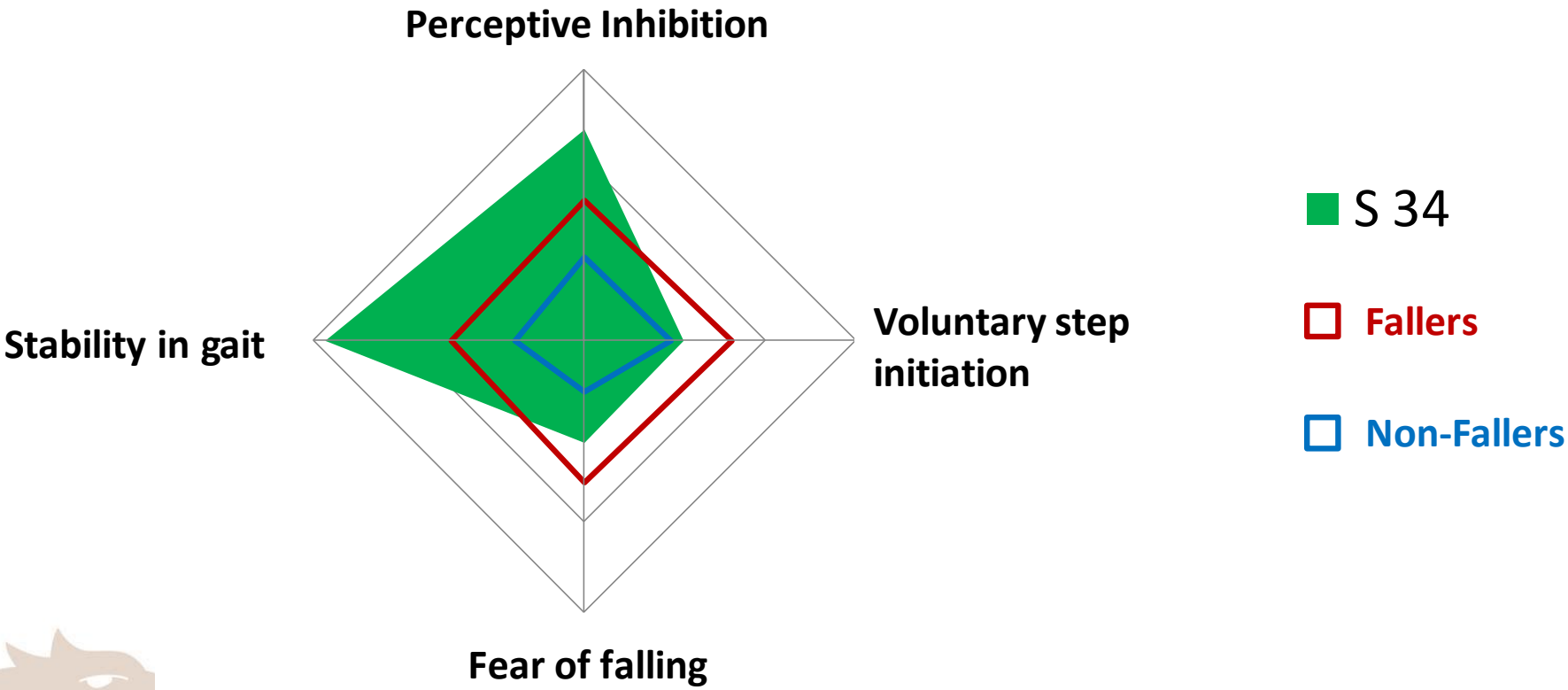
Balance assessment - Profile







Balance resources profile



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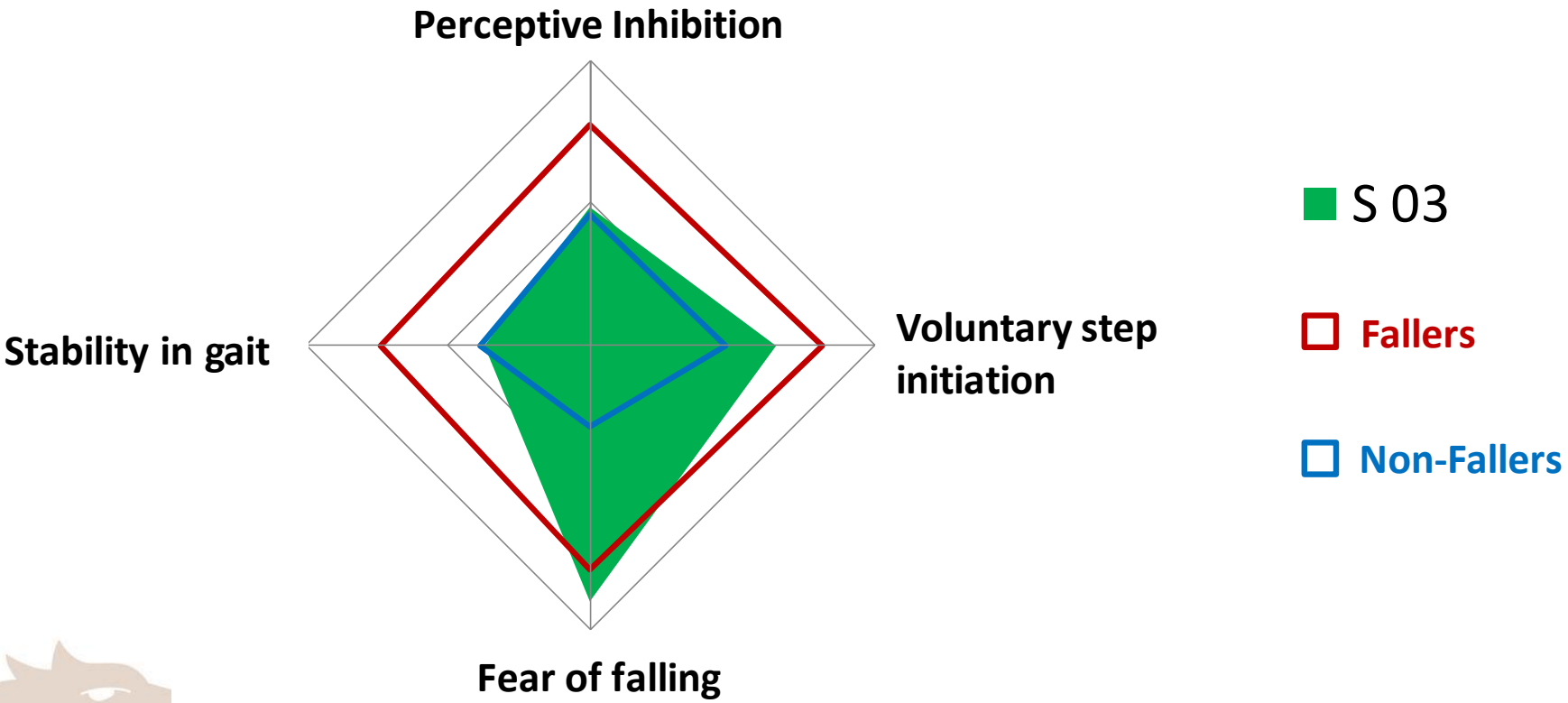
Balance resources profile



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Conclusion

Fear of falling was the best individual predictor

Multifactorial balance assessment seems to provide a more precise diagnosis.

Personalized **profile** may help organize fall prevention procedure
→ Individualization (elderly/pathological people)
→ Better planification (clinician)
→ Better care?

Need for more **longitudinal** studies.

3. PERSPECTIVES

SMART AGEING AND HEALTHY LIFE Summer School - 23/09/2021

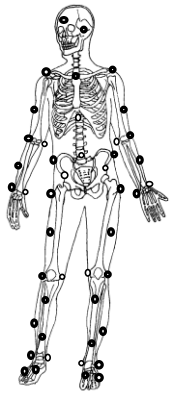
Co-funded by the Erasmus+ Programme of the European Union

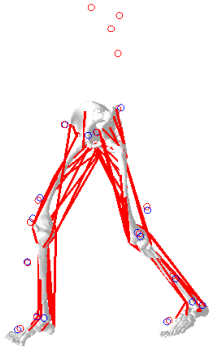
University of Poitiers

PPRIME Laboratory

Equipe RoBioSS (Robotics Biomechanics for Sports and Health)

Experiments





Modeling

Simulation

Measurement systems

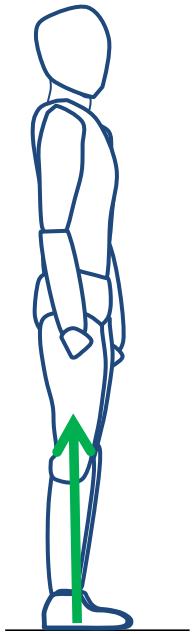
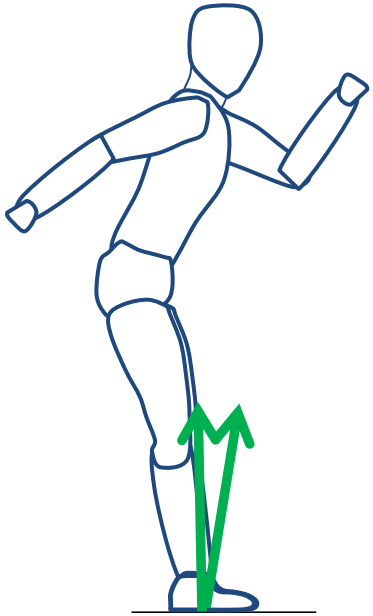
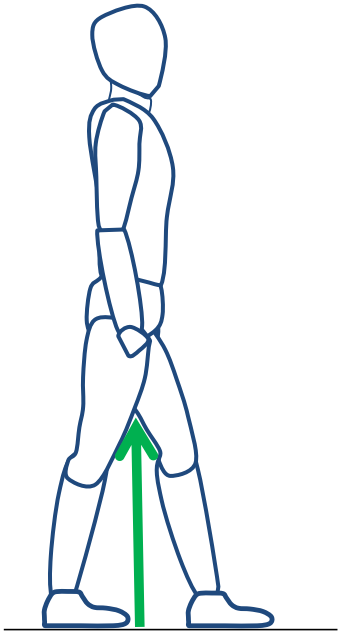
- Optoelectronic cameras
- Forceplates
- High frequency video cameras
- Force sensors
- Inertial sensors
- EMG and pressure sensors

Ongoing project



Identify the contribution of balance recovery mechanisms

Three main balance recovery/maintain mechanisms

https://www.youtube.com/watch?v=lk_Pwu7nf1U

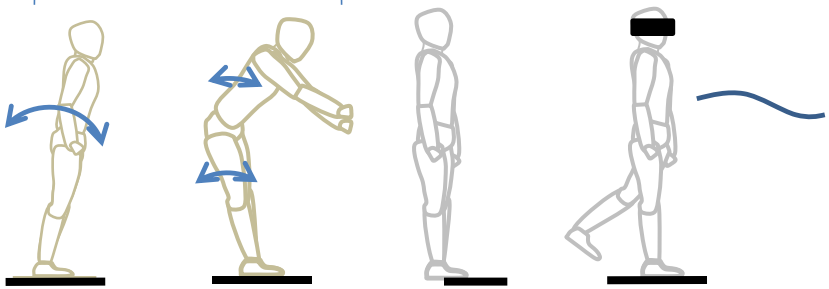
https://www.youtube.com/watch?v=woCdjbsjbPg&t=1s

Hof (2007) *The equations of motion for a standing human reveal three mechanisms for balance*, Journal of Biomechanics, 40, 451-457

Ongoing project

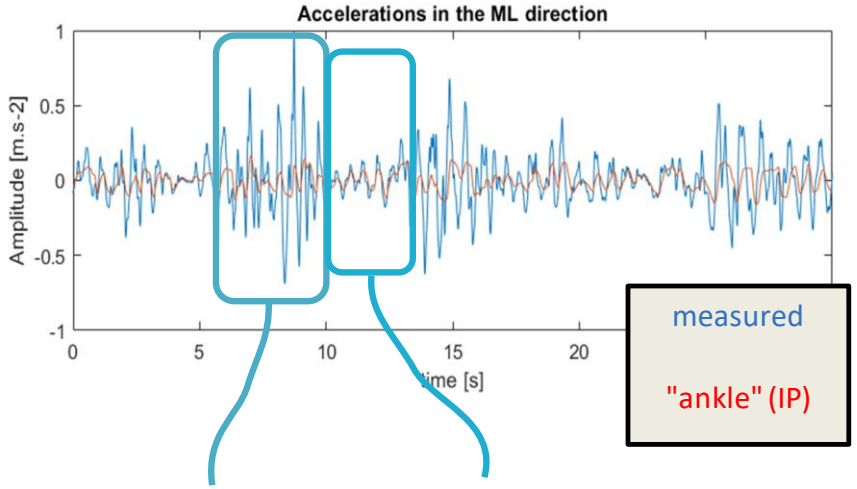


Slowly!



AP AP AP ML

% ankle	85	87	43	25
% hip	15	13	57	75



Intermittent use of the « hip » strategy

Complete use of the « ankle » strategy

→ Apply this to elderly/pathological populations?

Vaur et al., *Intermittent mechanical actions completing inverted-pendulum-like actions for standing balance in humans,* Computer Methods in Biomechanics and Biomedical Engineering, accepted

Perspective project

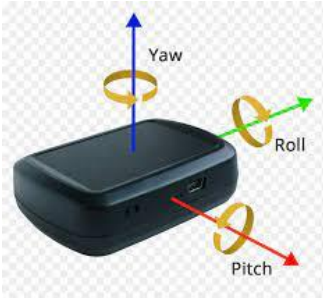
Assessment of dynamic variability in population at risk of fall to improve personalized diagnostic

→ Coordination flexibility is reduced with age and pathology

→ Stability : ability of a system to resist to perturbations (Van Emmerik et al., 2016)

Assessment in the clinical environment

→ Using Inertial Measurement Units (IMUs)
→ Compatible with clinical environment constraints
→ Measure in more “ecological” situations than in the lab



Van Emmerik et al. (2016) *Comparing dynamical systems concepts and techniques for biomechanical analysis*, Journal of Biomechanics, 40, 451-457

Perspective project

Objectives

→ Characterize risk of falling from dynamic balance measurements

→ Compare variability measures between steady-state and reactive movements, in elderly and/or pathological people

→ Continue the effort towards personalized diagnosis of fall risk level and fall prevention procedures

Main difficulty right now

Team with a clinical partner to test our paradigm in a real clinical environment.
If you are interested, please let us know!

Thank you for your attention

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